residual skin lesions. The lymphadenopathy had regressed, but the eosinophilia persisted (10% or 830/ml). No side-effects of long-term topical therapy were encountered. The psychological withdrawal lessened progressively with the improvement in the skin condition.

DISCUSSION

The female patient was mentally defective; this may occur in KS. The male patient, on the other hand, was intellectually normal although psychologically depressed. He was extensively investigated for immunological, lymphoreticular and neoplastic abnormalities, which were not detected. The striking eosinophilia and elevated IgE level are consistent with parasitic infestation. No defect of humoral or cell-mediated immunity was demonstrated. The patient's initial autistic behaviour appears to have been the result of the psychological impact of his skin disorder rather than its cause. In fact, he became progressively more sociable as the KS responded to treatment.

Results of *in vivo tests of* cell-mediated immunity were abnormal, whereas those of *in vitro* tests were within the normal range. It is difficult to offer a ready explanation for this phenomenon. However, it has frequently been encountered by our immunologist (A. Rabson — personal communication).

We should like to thank Mr J. Newlands of the Entomology Department of the South African Institute for Medical Research for his enthusiastic assistance.

REFERENCES

1. Danielssen, D. C. and Boeck, W. (1848): *Traité de la Spedalskhed ou éléphantiasis des Grecs.* Paris: J. B. Baillière.
2. Parish, L. Ch. and Lomholt, G. (1976): Int. J. Derm., **15**, 747.
3. Schiff, B. L. and Ronchese, F. (1964): Arch Derm., **89**, 326.
4. Kocsard, E. (1967): Cutis, **3**, 41.
5. Wells, G. C. (1952): Brit. med. J., **2**, 18.
6. Walshe, M. M. (1967): W. Ind. med. J., **16**, 57.
7. Burks, J. W. jun., Jung, R. C. and George, W. M. (1956): Arch. Derm., **74**, 131.
8. Epsy, P. D. and Jolly, H. W. jun. (1976): *Ibid.*, **112**, 193.
9. Dostrowski, A., Raubitscher, F. and Sagher, F. (1956): Dermatologica, **113**, 26.
10. Mariotti, A. and Rifelli, G. (1968): Arch. ital. Derm., **35**, 289.
11. Baer, R. L. and Witten, V. H. (1957): *Year Book of Dermatology.* Chicago: Year Book Medical Publishers.
12. Ressa, P. (1968): Minerva Derm., **43**, 543.
13. Sutton, R. L. jun. (1956): *Diseases of the Skin,* 11th ed. St Louis: C.V. Mosby.
14. Zumpt, F. (1972): *Essays on Tropical Dermatology,* vol. 2, p. 199. Amsterdam: Excerpta Medica.
15. Ingram, J. T. (1951): Brit. J. Derm., **63**, 311.
16. Hubler, W. R. and Clobaugh, W. (1976): Arch. Derm., **112**, 179.
17. Prakken, J. R. and van Vloten, T. J. (1949): Dermatologica, **99**, 131.
18. Onderscheke, K., Kutzer, E. and Richter, H. E. (1968): Z. Jagdwiss., **14**, 12.

Pulmonary Arteriovenous Fistulas

A Case Presentation and Review of the Literature

J. Z. PRZYBOJEWSKI, F. MARITZ

SUMMARY

A young woman had a pulmonary arteriovenous fistula localized to the right lower lobe. The presence of a patent foramen ovale (atrial septal defect) detected pre-operatively allowed for a unique investigation of this case. Her successful surgical management is outlined and the literature is reviewed.

S. Afr. med. J., **57**, 366 (1980).

Since the first description by Churton,[1] over 400 cases of pulmonary arteriovenous fistula (PAVF) have been described in the literature. The vast majority of cases are congenital, and about a third have been associated with hereditary haemorrhagic telangiectasia (Rendu-Osler-Weber disease). Secondary or acquired PAVFs have stimulated much controversy as to their pathogenesis. Very occasionally they are associated with conditions such as cirrhosis of the liver,[2] mitral stenosis,[3,4] pulmonary schistosomiasis,[5] and metastatic carcinoma.[6] The clinical features of this condition are most varied, in keeping with the diverse pathophysiology. Awareness of the potentially fatal cerebral complications is of paramount importance, since in the majority of instances a PAVF is easily correctable. The coexistence of a patent foramen ovale (atrial septal defect), allowing for accurate pre-operative haemodynamic and cine angiographic assessment, has only been reported on one previous occasion,[7] in a young girl with multiple small PAVFs who was inoperable. The present case of a single fistula appears to be the first documented one in which surgical correction was possible.

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Date received: 1 October 1979.

CASE REPORT

A 22-year-old nurse was admitted to the Cardiac Unit, Tygerberg Hospital; she had been transferred from a hospital in South West Africa, where she had been admitted some 2 weeks previously. Prior to that admission she had a 6-week history of peripheral cyanosis, grade III dyspnoea and occasional, nonspecific, stabbing chest pain. There was also a questionable single convulsion (type unknown). She had had no orthopnoea, paroxysmal cardiac dyspnoea, palpitations, cough or haemoptysis, but had

suffered from frontal headaches for many years. She was a non-smoker. At the age of 4 years she apparently underwent a 'brain operation' at another hospital, the details of which were unobtainable, but according to her parents she recovered completely from this.

Both her parents were healthy, apart from a history of renal calculi and diabetes mellitus. She had five brothers and four sisters, one of whom had died of gastric carcinoma.

On admission to the referring hospital in South West Africa, she had peripheral cyanosis. Her jugular venous pressure was 2 cm elevated and there was fixed splitting of the pulmonic component of the second heart sound. There was clubbing of the fingers but no congestive cardiac failure. A chest radiograph was reported as showing prominent hilar shadows with oligaemia and right ventricular enlargement. The haemoglobin concentration was 19 g/dl and the erythrocyte sedimentation rate 1 mm/h (Westergren). The ECG showed T-wave inversion in leads V3 and V4. A skull radiograph demonstrated calcification within the brain. Her doctors then made a provisional diagnosis of an Eisenmenger syndrome and referred her to Tygerberg Hospital.

Examination on admission to Tygerberg Hospital revealed a plethoric young woman with definite peripheral cyanosis but questionable central cyanosis. There was evidence of mild clubbing of the fingers, but not the toes. Her radial pulse was regular (76/min) and normal in quality. All peripheral pulses were normal and there was no radiofemoral delay. The blood pressure was 110/70 mmHg and jugular venous pressure 2 cm with an easily discernible 'a' wave. The apex beat was normal but a slight left parasternal heave, suggestive of right ventricular enlargement, was noted. Auscultation of the heart revealed a fairly prominent pulmonic component of the second heart sound, which was widely split on expiration, but not fixed. There were no murmurs present. The remainder of the clinical examination was negative.

A full blood count revealed the following: haemoglobin 18,1 g/dl; leucocytes 8 500/μl (normal differential count); packed cell volume 54,7%; mean corpuscular haemoglobin 28,8 pg; mean corpuscular haemoglobin concentration 33,0%; mean corpuscular volume 89 fl; platelets 220 000/μl; erythrocyte sedimentation rate 2 mm/h (Westergren). Blood gas analysis (off oxygen) and acid-base status were as follows: Po_2 6,0 kPa% (normal 12,0 - 14,7 kPa%); Pco_2 4,8 kPa% (normal 4,6 - 6,0 kPa%); base excess 1 mmol/l; pH 7,44; CO_2 24,5 mmol/l (normal 24 - 30 mmol/l). A resting ECG showed a sinus rhythm, a heart rate of 76/min, a PR interval of 0,12 second and a mean QRS axis of 82°. There was nonspecific, generalized T-wave flattening.

A chest radiograph (Fig. 1) revealed a 'mitralized' heart with normal lung fields, while a skull radiograph (Fig. 2) showed the presence of brain calcification.

The urine was normal.

The blood chemical values were within normal range, including those for K, Na, Cl, creatinine, urea, uric acid, glucose, total bilirubin, direct bilirubin, total protein, albumin, alkaline phosphatase, globulin, lactic dehydrogenase, aspartate transaminase and alanine transaminase. Results of immunological tests — LE cells, antinuclear factor, antibodies against thyroid and mitochondria — were all normal.

An EEG, done because of the history of possible convulsions and the presence of brain calcification, was normal. Since PAVF was strongly suspected at this stage, a perfusion lung scintigram, using ^{99m}Tc-labelled albumin

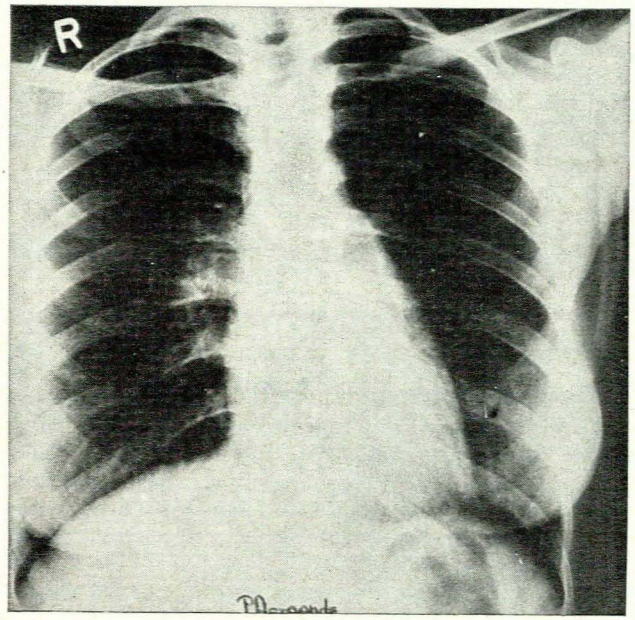

Fig. 1. Chest radiograph showing the 'mitralized' heart and normal lung fields.

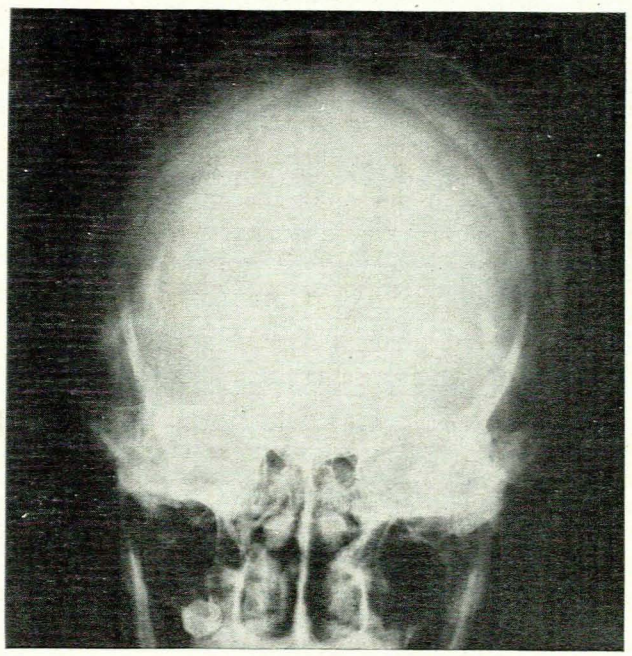

Fig. 2. Skull radiograph: the calcified focus in the left side of the brain can be seen.

microspheres, was requested. This showed no 'cold areas' in the lungs, but was abnormal in that the kidneys were outlined, signifying a definite PAVF which was too small to show up in the lungs (Fig. 3). For definitive diagnosis cardiac catheterization was undertaken.

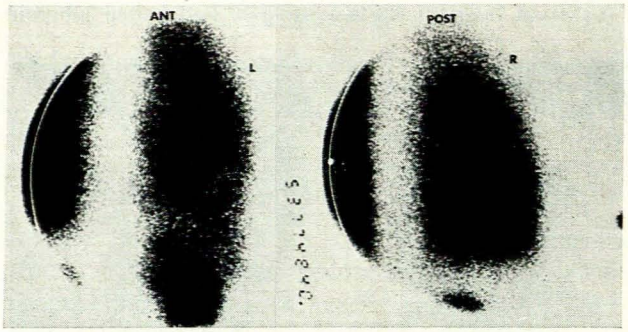

Fig. 3. Perfusion lung scintigrams showing left lung and kidney, and right lung and upper pole of right kidney. No 'cold' areas can be seen in the right lower lobe.

Cardiac Catheterization

This investigation was performed using the percutaneous femoral Seldinger technique from the right groin under local anaesthesia. A 7F Goodale-Lubin catheter was used for measuring pressures and saturations on the right side and a 7F Rodriques-Alvarez catheter for contrast injection. A 7F Cordis pigtail catheter was inserted to measure pressures and saturations on the left side and for cine angiography. The intracardiac pressures and oximetry results are indicated in Tables I and II respectively. Haemodynamic calculations are outlined in Table III. As can be seen, there was no evidence of pulmonary hypertension and the pressures in both atria were normal. There was a left-to-right shunt of 7% (probably via the patent foramen ovale) and a right-to-left shunt of 26% (almost certainly via the PAVF).

The following cine angiograms were done: left atrial (shallow half-axial left anterior oblique projection); left ventricular (right anterior oblique projection); ascending aorta (left anterior oblique projection); right pulmonary artery (anteroposterior and left lateral biplane). Finally, a pulmonary angiogram (anteroposterior; cut films at 2 per second for 8 seconds) was filmed (Anderson and Ohlson table).

As can be seen from Fig. 4, there was 'kissing' of the two catheters inserted, i.e. the right-sided catheter advanced into the right pulmonary artery and the other right-sided catheter advanced into the right lower pulmonary vein (via the patent foramen ovale) and further into the PAVF. Furthermore, as can be seen from Tables I and II, the pressures and oxygen saturations measured by these two catheters were identical. The selective right pulmonary cine angiogram (Fig. 5) clearly outlines the PAVF, which was situated between the right pulmonary artery and right lower pulmonary vein.

Surgical Correction

A right thoracotomy was performed. The right inferior pulmonary vein was markedly enlarged and this vessel was tied off. Four arteries were noted in the interlobar fissure and three apical segmental arteries were identified. A right lower lobectomy was then performed. Blood transfusion was unnecessary and no complications were encountered during the operation or afterwards. The excised right lower lobe measured 14 × 12 × 7 cm and pathological examination confirmed the presence of a PAVF.

TABLE I. INTRACARDIAC PRESSURES

Catheter position	Pressure (mmHg)	Comment
Right atrium	'a' wave 2 (mean 1) 'v' wave 1	Normal
Right ventricle	17/0 - 1	Normal
Main pulmonary artery	17/3 (mean 8)	No pulmonary stenosis or hypertension
Ascending aorta	111/64 (mean 80)	Normal
Left ventricle	111/1 - 6	No aortic stenosis
Left atrium	'a' wave 6 (mean 5) 'v' wave 5	Normal No mitral stenosis
Pulmonary capillary wedge (left)	'a' wave 8 (mean 5) 'v' wave 6	Normal
Right pulmonary artery	20/4	Equal pressures due to PAVF
Right inferior pulmonary vein	20/4	

TABLE II. OXIMETRY RESULTS

Catheter position	O_2 saturation	Comment
Superior vena cava	70	
Right atrium (high)	69	Left-to-right shunting via the patent foramen ovale (atrial septal defect)
Right atrium (mid)	76	
Right atrium (low)	75	
Inferior vena cava (at diaphragm)	72	
Upper right pulmonary vein	98	
Left atrium	84	
Upper left pulmonary vein	95	Right-to-left shunting via right lower PAVF
Left atrium	84	
Lower right pulmonary vein	69	
Right pulmonary artery	69	
Main pulmonary artery	72	No obvious shunting (left-to-right or vice versa) at pulmonary artery, ventricular or atrial levels
After oxygen	75	
Central aorta	90	
After oxygen	92	
Right ventricle (high)	73	
Right ventricle (low)	72	
Right atrium (mid)	73	
Right atrium (low)	72	
Inferior vena cava (at diaphragm)	70	

TABLE III. HAEMODYNAMIC CALCULATIONS

Parameter	Result
Pulmonary blood flow (l/min)	3,2
Index (Fick) (l/min/m²)	2,3
Systemic blood flow (l/min)	3,9
Index (Fick) (l/min/m²)	2,7
Pulmonary vascular resistance (U)	1,5
Index (U/m²)	2,5
Systemic vascular resistance (U)	20,5
Index (U/m²)	29,6
Resistance ratio (pulmonary/systemic) (%)	7
Left-to-right shunt (oximetry) (%)	7
Right-to-left shunt (oximetry) (%)	26

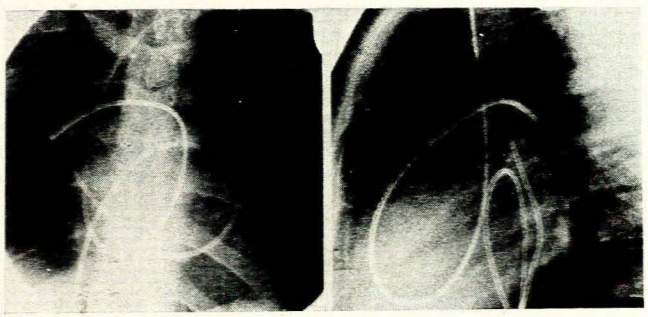

Fig. 4. Plain cine angiograms (anteroposterior and left lateral) showing 'kissing' of catheters advanced via the right pulmonary artery and right lower pulmonary vein into the PAVF.

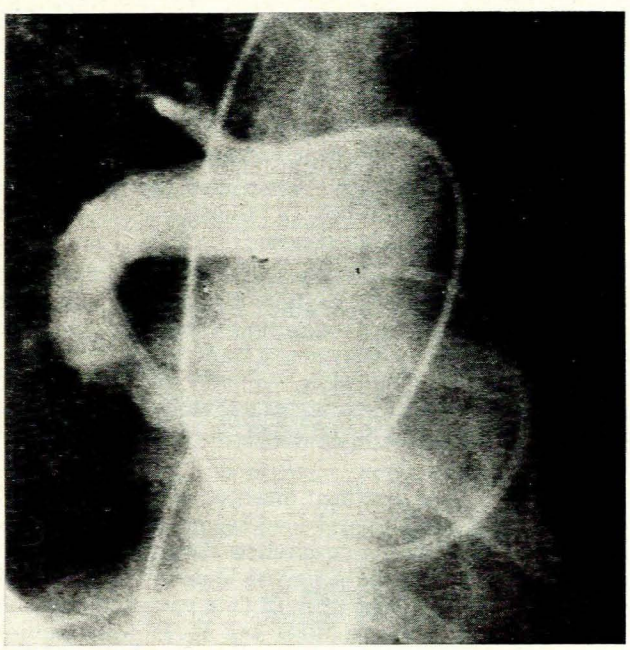

Fig. 5. Selective right pulmonary cine angiogram clearly showing the PAVF draining into the left atrium.

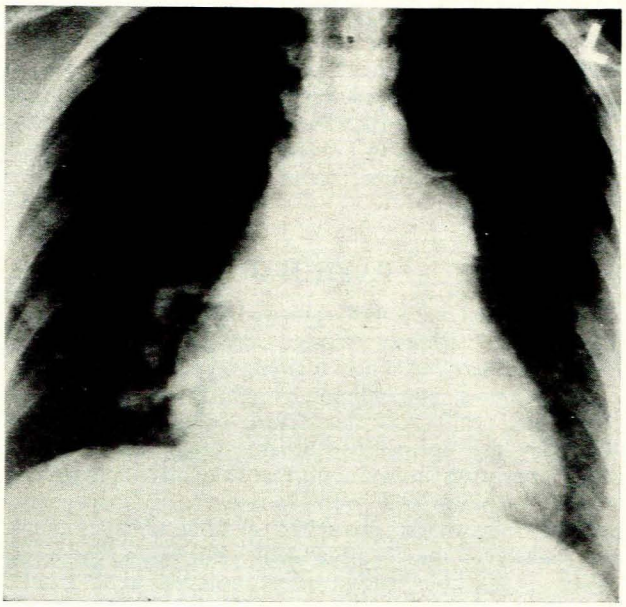

Fig. 6. Chest radiograph showing the 'serpiginous' structure, viz. the PAVF, in the right lower lobe. A dilated main pulmonary artery is also visualized.

Postoperative blood gas analysis and acid-base status were as follows: P_{O_2} 12,8 kPa%; P_{CO_2} 4,9 kPa%; base deficit −5 mmol/l; pH 7,34; CO_2 19,4 mmol/l. These results clearly indicated a correction of the initial defect, and clinical examination showed no signs of central and peripheral cyanosis. As expected, however, the patient still showed signs of clubbing and plethora.

Postoperative Cardiac Catheterization

Two weeks after her operation right heart catheterization was repeated and confirmed that oxygen saturations and pressures were normal. The catheter could not be passed through the previously patent foramen ovale despite numerous attempts, and it was therefore assumed that this had closed as a result of surgery. Left heart catheterization and cine angiography were considered unnecessary. The patient was discharged. When seen as an outpatient a month after discharge, she was asymptomatic and the clinical examination was unremarkable. The patient then returned to South West Africa, and according to her parents she is asymptomatic a year postoperatively.

HISTORICAL PERSPECTIVES

The first reported autopsy finding of multiple haemangiomatous lesions in the lungs was that of Churton[7] in 1897. He termed these aneurysms of the pulmonary artery, but it would appear that they were PAVFs. His report was followed by that of Wilkens,[8] who detailed the autopsy findings in a woman who succumbed as a result of a massive pulmonary haemorrhage and who had multiple PAVFs. Before death an unexplained bruit over the lungs had been noted. The first retrospective explana-

tion of autopsy findings of PAVF was made by Rhodes,[9] and Smith and Horton[10] published the first clinical report. Hepburn and Dauphinee[11] reported the first successful surgical cure by pneumonectomy, carried out by Shenstone. The first review of PAVF by Giampalmo[12] in 1951 reported on a total of 36 proven cases. Subsequently further reviews were published,[3,13] the last being that of Moyer *et al.*[14] in 1962.

PATHOLOGY

This has been very well reviewed by Le Roux.[3] PAVFs have been variously termed congenital arteriovenous varices, cavernous haemangiomas, multiple pulmonary haemangiomas, and pulmonary arteriovenous aneurysms. They are really vascular hamartomas, which signifies that they are normal constituents of an organ, viz. the lung, appearing in an abnormal way. As both the pulmonary arteries and veins originate from a common capillary plexus, the possibility of abnormal communication between these components during embryogenesis exists. It is thought that they probably arise from an incomplete fusion of the venous and arterial septa, or otherwise from disintegration of hypoplastic septa. Anatomical pulmonary arteriovenous communications of larger diameter than capillaries have been shown to exist.[4,15,16] There is controversy as to whether these channels give rise to pathological fistulas under various influences (see 'Association with Pulmonary Hypertension' discussed later). The known relationship to Rendu-Osler-Weber disease signifies development as part of a generalized congenital vascular hypoplasia. PAVFs are found in close proximity to the visceral pleura, and are sometimes calcified.[17] Basically they consist of vascular channels lined by endothelium and supported by connective tissue of varying proportion. Usually the arterial supply is from pulmonary artery branches, but it sometimes arises from the systemic circulation by way of the bronchial arteries,[18] intercostal arteries, or directly from the aorta. Prior to joining the fistula the arterial supply is sometimes reduced to the calibre of an arteriole. The venous drainage distal to the fistula is usually via distinct pulmonary veins into the left atrium. However, this must be distinguished from the much more rare congenital communication between the pulmonary artery and the left atrium, which has been considered a variant of PAVF.[19,20] These lesions are not situated peripherally.

It has been postulated that an additional blood supply from the visceral and parietal pleura is present, as the fistula and adjacent lung tissue are sometimes adherent to the parietes.

As the vessel walls become increasingly dilated as a result of transmitted arterial pressure (systemic and pulmonary), degenerative changes are noted. Thus, haemorrhage into adjacent tissue occurs with vessel rupture and is followed by calcification.

PATHOPHYSIOLOGY

The essential defect is a right-to-left shunt from pulmonary artery to pulmonary vein. This physiological abnormality was demonstrated by Friedlich *et al.*,[19] Gray *et al.*,[21] and Hultgren and Gerbode.[22] Arterial desaturation ensues, with resultant cyanosis (peripheral and central) if it is severe enough. The hypoxaemia is a stimulus to erythropoiesis with ensuing polycythaemia.[9,23]

As anticipated, the reticulocyte count is often raised. An increase in blood volume is also seen, but this is usually due to an increase in the red cell volume with a normal plasma volume. After successful surgery the haematological values return to normal within weeks or months.

Waldhausen and Abel[24] produced experimental PAVF in dogs and studied the acute haemodynamic responses on opening the fistulas. They noted that although the heart rate remained constant, the cardiac output increased by some 11%, mainly through a rise in stroke volume. There was an accompanying fall of 11% in pulmonary artery pressure and a rise of 44% in the left atrial pressure. This gave rise to a drop in pulmonary vascular resistance (excluding the fistula) of 18%. When the lung was denervated, pulmonary vascular resistance distal to the shunt rose, signifying reflex vasodilatation of the lung in response to opening of the fistula.

CLINICAL FEATURES

The classic clinical triad consists of dyspnoea on effort, cyanosis and clubbing. Patients usually present with symptoms in the third decade, but these may well be present at a much earlier age (approximately 30% of the 140 cases reviewed by Stringer *et al.*[13] presented in childhood). Of the 63 patients reported by Dines *et al.*[18] 44% had symptoms (especially dyspnoea, cyanosis and clubbing). In patients with associated hereditary haemorrhagic telangiectasia (Rendu-Osler-Weber disease[25]) the presenting symptom may be epistaxis, haematuria, melaena, haemoptysis or cerebrovascular haemorrhage.

Polycythaemia *per se* is sometimes the predisposing cause of cerebral haemorrhage, which may manifest as focal or generalized convulsions.

Symptoms and physical signs are not necessarily more common in patients with multiple fistulas than with single ones, but the size of a single fistula often determines the absence or presence of symptoms and signs; those over 2,0 cm in diameter are often symptomatic. In the study of 63 patients by Dines *et al.*,[18] 41 patients had single and 22 multiple fistulas; in 5 patients the fistulas were bilateral.

It is common to hear a continuous murmur over the fistulous mass, with maximal intensity in late systole and early diastole, and usually loudest on deep inspiration but almost inaudible on expiration. Sometimes no bruit can be detected. In the series of Dines *et al.*,[18] a bruit was present in 37 cases (60%). This was continuous in 22 patients with a single fistula and in 15 with multiple fistulas. It was noteworthy that a bruit was heard in 70% of patients with hereditary haemorrhagic telangiectasia and in 35% of those without.

ASSOCIATION WITH HEREDITARY HAEMORRHAGIC TELANGIECTASIA

It has been known for many years that there is a close relationship between Rendu-Osler-Weber disease and PAVF. In one series of 35 patients,[26] 49% with PAVF had a family history of hereditary haemorrhagic telangiectasia, and 66% had telangiectasia on clinical examination. In another series of 27 patients who had PAVF, 18 were members of a family who were known to have the condition.[27] Dines *et al.*[18] noted that there was an increased incidence of multiple fistulas, an increased rate of fistula growth, and an increased frequency of complications in patients with concomitant hereditary haemorrhagic telangiectasia.

ASSOCIATION WITH PULMONARY HYPERTENSION

If one excludes the presence of mitral stenosis then the association of pulmonary hypertension with PAVF is extremely rare. To date, only 6 cases have been published. Sapru *et al.*[28] reported 3 cases, Le Roux *et al.*[6] reported a case with pulmonary schistosomiasis, and Sperling *et al.*[29] described 2 women who had had numerous pregnancies; the lastnamed suggested multiple pulmonary thrombo-embolism, predisposed to by high levels of endogenous oestrogens, as a possible causative factor. Unfortunately, the exact incidence of pulmonary hypertension in patients with PAVF is unknown due to the paucity of haemodynamic data. Most of the published studies indicate a normal to low pulmonary arterial pressure in man,[14,30] as well as in the experimental animal.[24,31] In the cases of Sperling *et al.*[29] there is a strong suggestion that pulmonary hypertension preceded the appearance of the PAVF.

Studies in man[15] have demonstrated the presence of small pulmonary arteriovenous shunts, localized to the apices of the various lung segments close to the visceral pleura.[32,33] These are the sites of pathological arteriovenous fistulas. It has been shown that these 'physiological' shunts are increased with increasing pulmonary artery pressure,[34] which suggests that pulmonary hypertension is a possible factor in the aetiology of PAVF.

Patients with mitral stenosis have been documented as having PAVF,[3,4] suggesting that the pulmonary hypertension secondary to the valve lesion expands normal microscopic arteriovenous channels. However, the rarity of this association casts great doubt on this possible pathophysiological mechanism.

Investigators have shown that a significant degree of pulmonary shunting can occur in patients with underlying chronic pulmonary hypertension from whatever cause.[35] Cirrhosis has been known to be associated with pulmonary hypertension,[36,37] and microscopic PAVFs[2] have been thought not to result from portal hypertension, but rather from an unknown normal influence on the pulmonary vascular tree.

Exogenous oestrogen therapy, as a potential cause of pulmonary hypertension, has been suggested by some workers[28] to lead to PAVFs. Endogenous oestrogens have also been postulated as a cause of repeated pulmonary thrombo-embolism and subsequent pulmonary hypertension with PAVF development.[29]

RADIOGRAPHIC AND ANGIOGRAPHIC FEATURES

Cardiomegaly is usually conspicuously absent, and if it is present due consideration must be given to probable concomitant cardiac disease, for example mitral stenosis. In contrast, cardiomegaly as well as increased cardiac output is often encountered in patients with peripheral (systemic) arteriovenous fistulas.

The most frequent site for PAVFs is the right lower lobe, and approximately a third of the reported cases have occurred here. Fig. 6 is a classic example in another woman patient who presented with the typical triad of symptoms and a loud fistulous murmur heard over the right lower chest. The 'serpiginous' nature of the fistula is very clearly seen. The left lower lobe is the next most common site, followed by an equal frequency in the left upper lobe and right middle lobe. These fistulas are typically peripheral, circumscribed and non-calcified and communicate with hilar vessels. Calcification is very rare.[17,38] Rib notching may indicate arterial supply from intercostal arteries.[39] At times more than one lesion may be seen.[40] Several authors have also documented lesions which have increased in size and number on radiography.[18]

Fluoroscopy permits additional characteristics to be documented. Pulsation of the tumours can be visualized; changes in intrathoracic pressure modify the size, that is deep inspiration followed by forced expiration against a closed glottis (Valsalva manoeuvre) decreases the tumour mass, while deep expiration followed by forced inspiration against a closed glottis (Mueller's test) increases it.

Angiocardiography permits the accurate delineation of the tumours; most important is a picture which includes the arterial supply so that appropriate surgery can be applied. Selective cine angiography or cut films of the pulmonary artery branch give clear definition, especially in single or multiple large PAVFs. Aortography is done if the suspected arterial supply is from the systemic circulation. In the interpretation of the angiograms consideration must be given to possible clot formation within the fistula, as in this situation the plain chest radiograph will appear far more impressive. Tomography will probably also be more striking when compared with the angiograms.

Multiple small PAVFs usually only occur in Rendu-Osler-Weber disease, or in chronic obstructive pulmonary lung disease. Angiographic demonstration of these lesions can be most difficult and unsatisfactory.[41] The technique of peripheral pulmonary wedge angiography was first used in this situation by Jacobsen *et al.*[42,43] Subsequent reports[44,45] indicated success with this technique.

DIFFERENTIAL DIAGNOSIS

Cyanotic congenital heart disease, for example patent ductus arteriosus, can sometimes cause confusion. However, the ECG usually permits differentiation from PAVF

and cardiac catheterization removes all doubt. In asymptomatic patients routine mass radiography assumes importance and the diagnosis may be aided by tomography. Alternative diagnoses include tuberculomas, coccidioidomycosis, histoplasmosis, bronchogenic carcinoma, bronchial adenomas, metastatic lesions, hamartomas, mesotheliomas, benign cysts, diaphragmatic hernias, pulmonary parenchymal haemorrhage and intrapleural haemorrhage. Since more than half of the patients with PAVF have polycythaemia, the condition must be differentiated from polycythaemia vera; this is usually not difficult as the latter condition presents with increased white cell counts as well as splenomegaly and normal arterial oxygen saturation.

Recurrent small pulmonary emboli can cause almost identical symptoms, but are usually followed by pulmonary hypertension, rare in PAVF. The same considerations apply to primary pulmonary hypertension. Cor pulmonale should be kept in mind in the differential diagnosis.

In the presence of the Rendu-Osler-Weber syndrome the strong possibility of PAVFs should immediately be considered.

COMPLICATIONS

Perhaps the sequelae of neurological complications are the most devastating. It has been reported that some 30% of patients have cerebral symptoms. These are usually attributed to polycythaemia, cerebral thrombosis, or cerebral arteriovenous malformation (in those with Rendu-Osler-Weber disease); to date there have been no reports of concomitant pulmonary and cerebral arteriovenous fistulas. The incidence of cerebral abscess and meningitis in PAVF is said to be as high as that in congenital heart disease.[46] They are most frequent in the third to fifth decade and are usually associated with a high mortality.[47] This may well be due to the delays in diagnosis and in subsequent surgical correction, owing to lack of recognition of this association. Also, surgical removal of the lung lesion may avert recurrence of the potential life-threatening cerebral abscess, which may be the presenting symptom.[48] It is interesting to speculate whether our patient did in fact have a cerebral abscess as a child as a complication of PAVF; this would have been most unusual as this complication occurs much later in life. Haemorrhage, especially epistaxis, is common and is usually a feature in patients with concomitant hereditary haemorrhagic telangiectasia. On occasion haemoptysis may be the presenting symptom.[49] Another less common complication is massive, fatal pleural haemorrhage.[50] Air embolism after rupture of a pulmonary vessel and giving rise to haemoptysis and convulsions has also been a postulated complication.[51] Infection, in the guise of bacterial endocarditis, has been infrequently reported.[52,53]

Iatrogenic complications related to angiocardiography have been documented. Cardiac rupture,[54] fatal pulmonary oedema,[55] and severe haemoptysis[56] are the most important.

PRE-OPERATIVE DIAGNOSTIC TECHNIQUES

Only the more recent developments in diagnostic technique will be discussed here.

Swan-Ganz Catheterization

Harrow *et al.*[57] reported the pre-operative evaluation of a patient with a solitary left lower PAVF, who had coexistent chronic obstructive pulmonary disease and a previous anterior myocardial infarction. The patient had marked exercise intolerance and it was not certain whether tolerance would improve significantly after operation in view of the concomitant ischaemic heart disease and pulmonary involvement. A balloon-tipped (Swan-Ganz) catheter was inserted and the proximal end of the fistula occluded by inflating the balloon. Arterial blood gas was analysed before and after exercise, initially with the balloon deflated and subsequently after inflation. The degree of right-to-left shunt was calculated before and after the fistula had been excluded from the pulmonary circulation. Because of the marked shunting and the considerable improvement that followed occlusion of the fistula, the malformation was excised. Two months later the Swan-Ganz catheterization was repeated; predicted and actual reduction in shunt fraction and the rise in resting arterial oxygen pressure (Pao_2) were comparable. Thus, this new technique provided an accurate estimate of the postoperative physiological results.

Contrast Echocardiography

This is a minimally invasive technique,[58,59] and in conjunction with perfusion lung scintigraphy can accurately estimate the degree of right-to-left shunting, as well as the location of the PAVF. The technique consists of the rapid injection of 2 ml indocyanine green dye into any peripheral vein, while recording an echocardiogram of the right ventricular outflow tract, aortic root and left atrium. This produces tiny bubbles which reflect ultrasound during the passage through the right side of the heart.[60] These bubbles are usually filtered by the pulmonary capillary bed and thus fail to appear in the left side of the heart. However, if a right-to-left shunt is present, part of the injectate bypasses the pulmonary bed and can thus be detected by the echocardiograph within the left atrium, left ventricle and aorta.

Perfusion Lung Scintigraphy

This is performed by intravenous injection of ^{99m}Tc-labelled albumin microspheres 10 - 15 μm in diameter. These particles usually collect in the pulmonary capillary bed and so do not enter the systemic circulation. However, in the presence of a PAVF, these microspheres enter the systemic circuit and would show up as a 'cold' area (corresponding to the fistula on a straight radiograph) in the lungs. This is a rapid, safe and accurate method for diagnosis.

TREATMENT

Almost without exception the treatment of choice is a minimal resection to include the entire removal of the PAVF. The various surgical procedures employed include ligation of the fistula, resection of the fistula,[61-64] segmental resection, wedge resection, and lobectomy.[65] Because multiple fistulas are common and some may not be visualized radiographically, and also because some of these intially missed lesions may subsequently enlarge, a policy of conservative surgery is advocated. Packard *et al.*[66] and other workers have performed ligation of the supplying and draining vessels, but this approach has been known to give rise to PAVFs subsequently needing segmental resection.

Dines *et al.*[38] indicated extremely favourable surgical results in their review of the 36 out of 63 patients operated upon and followed up for a mean of 8 years. Their operative approach was markedly conservative; nobody died, morbidity was minimal and only one fistula recurred. Among the remaining 27 patients who were treated medically, there were 6 deaths. As a result of their study they proposed operation for patients who were symptomatic and had large shunts, patients with enlarging fistulas, patients with multiple fistulas if these were well localized, and patients in whom the fistula had a systemic blood supply.

Biancalana and co-workers[65] operated successfully on all their 8 patients, with a follow-up period of 7 - 11 years. They stressed that surgery is the only treatment, even in non-cyanotic patients, on account of the known complications, albeit minor and infrequent, with even small fistulas. The decision to operate is usually most difficult in the patient with multiple lesions. In this situation, the chance of progression is very real, but the chance of complete cure is small. A conservative medical approach is often indicated in the elderly, especially if the lesion has remained constant in size for a long time. More recently, Taylor *et al.*[67] pioneered the technique of therapeutic embolization of the pulmonary artery in a patient who had had a previous lobectomy for a fistula and who subsequently developed another. The procedure was carried out by the percutaneous femoral vein technique of Seldinger, using 6 mechanical occluding devices (each consisting of a 5 cm segment of steel guidewire with 3 cm wool tails) designed by Gianturco.[68] The patient was thus saved a second thoracotomy and was free of symptoms and complications after 12 months' follow-up. In view of this conservative approach further reduction of pulmonary reserve was avoided. This technique appears to be useful for the 'high-risk' surgical patient.

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REFERENCES

1. Churton, T. (1897): Brit. med. J., **1**, 1223.
2. Berthelot, P., Walker, J. G., Sherlock, S. *et al.* (1966): New Engl. J. Med., **274**, 291.
3. Le Roux, B. T. (1959): Quart. J. Med., **28**, 1.
4. Steinberg, I. and McClenahan, J. (1955): Amer. J. Med., **19**, 549.
5. Le Roux, B. T., Gibb, B. H. and Wainwright, J. (1970): Brit. Heart J., **32**, 571.
6. Pierce, J. A., Reagan, W. P. and Kimball, R. W. (1959): New Engl. J. Med., **260**, 901.
7. Sanders, J. S. and Martt, J. M. (1962): Circulation, **25**, 383.
8. Wilkens, G. D. (1917): Beitr. klin. Tuberk., **38**, 1.
9. Rodes, C. B. (1938): J. Amer. med. Ass., **110**, 1914.
10. Smith, H. L. and Horton, B. T. (1939): Amer. Heart J., **18**, 589.
11. Hepburn, J. and Dauphinee, J. A. (1942): Amer. J. med. Sci., **204**, 681.
12. Giampalmo, A. (1951): Acta med. scand., **139**, 248.
13. Stringer, C. J., Stanley, A. L., Bates, R. C. *et al.* (1955): Amer. J. Surg., **89**, 1054.
14. Moyer, J. H., Glantz, G. and Brest, A. (1962): Amer. J. Med., **32**, 417.
15. Prinzmetal, M., Ornitz, E. M., Simkin, B. *et al.* (1948): Amer. J. Physiol., **152**, 48.
16. Tobin, C. E. and Zariquiey, M. O. (1950): Proc. Soc. exp. Biol. (N.Y.), **75**, 827.
17. Sloan, R. D. and Cooley, R. (1953): Amer. J. Roentgenol., **70**, 183.
18. Dines, D. E., Arms, R. A., Bernatz, P. E. *et al.* (1974): Mayo Clin. Proc., **49**, 460.
19. Friedlich, A., Bing, R. J. and Blount, S. G. (1950): Bull. Johns Hopk. Hosp., **86**, 20.
20. Kroeker, E. J., Adams, H. D., Leon, A. S. *et al.* (1963): Amer. J. Med., **34**, 721.
21. Gray, F., Lurie, P. R. and Whittenmore, R. (1952): Yale J. Biol. Med., **25**, 107.
22. Hultgren, H. N. and Gerbode, F. (1954): Amer. J. Med., **17**, 126.
23. Beierwaltes, W. H. and Byron, F. X. (1947): J. Amer. med. Ass., **134**, 1069.
24. Waldhausen, J. A. and Abel, F. C. (1966): Surgery, **59**, 76.
25. Hodgson, C. H., Burchell, H. B., Good, C. A. *et al.* (1959): New Engl. J. Med., **261**, 625.
26. Hodgson, C. H. and Kaye, R. L. (1963): Dis. Chest, **43**, 449.
27. Sluiter-Eringa, H., Orie, N. G. M. and Sluiter, H. J. (1969): Amer. Rev. resp. Dis., **100**, 177.
28. Sapru, R. P., Hutchison, D. S. C. and Hall, J. I. (1969): Brit. Heart J., **31**, 559.
29. Sperling, D. C., Cheitlin, M., Sullivan, R. W. *et al.* (1977): Chest, **71**, 753.
30. Gomes, M. R., Bernatz, P. E. and Dines, D. E. (1969): Ann. thorac. Surg., **7**, 582.
31. Takaro, T., Essex, H. E. and Burchell, H. B. (1951): Amer. J. Physiol., **165**, 513.
32. Tobin, C. E. (1966): Thorax, **21**, 197.
33. Anabtawi, I. N., Ellison, R. G. and Ellison, L. T. (1965): Ann. thorac. Surg., **1**, 277.
34. Ellison, L. T., Hall, D. P., Yeh, T. *et al.* (1961): J. appl. Physiol., **16**, 305.
35. Jose, A. D. and Milnor, W. R. (1959): J. clin. Invest., **38**, 1915.
36. Naeye, R. L. (1969): Circulation, **22**, 376.
37. Senior, R. M., Britton, R. C., Turino, G. M. *et al.* (1968): *Ibid.*, **37**, 88.
38. Jones, J. C. and Thompson, W. P. (1944): J. thorac. Surg., **13**, 357.
39. Stork, W. J. (1955): Amer. J. Roentgenol., **74**, 441.
40. Hales, M. R. (1956): Amer. J. Path., **32**, 927.
41. Cooley, D. A. and McNamara, D. G. (1954): J. thorac. Surg., **27**, 614.
42. Jacobson, G., Turner, A. F., Balchum, O. J. *et al.* (1965): Amer. J. Roentgenol., **93**, 868.
43. Jacobson, G. (1963): Clin. Radiol., **14**, 326.
44. Rigler, L. G. (1966): Ann. intern. Med., **64**, 1114.
45. Balchum, O. J., Jung, R. C., Turner, A. F. *et al.* (1967): Amer. J. Med., **43**, 178.
46. Tyler, H. R. (1973): Trans. Amer. neurol. Ass., **98**, 314.
47. Dyer, N. H. (1967): J. Neurol. Neurosurg. Psychiat., **30**, 563.
48. Thompson, R. L., Cattaneo, S. M. and Barnes, J. (1977): Chest, **72**, 654.
49. Janes, R. M. (1944): J. Surg., **31**, 270.
50. Moore, B. P. (1969): Thorax, **24**, 381.
51. Boerema, I. and Brilman, R. P. (1948): J. thorac. Surg., **17**, 705.
52. Maier, H. C., Himmelstein, A., Riley, R. L. *et al.* (1948): *Ibid.*, **17**, 13.
53. Stevenson, F. H. (1953): Lancet, **1**, 626.
54. Starkey, G. W. B. and Milstein, B. B. (1953): Guy's Hosp. Rep., **102**, 240.
55. Sisson, J. H., Murphy, G. E. and Newman, E. V. (1945): Bull. Johns Hopk. Hosp., **76**, 93.
56. Runström, G. and Sigroth, K. (1950): Acta med. scand., suppl. 246, p. 176.
57. Harrow, E. M., Beach, P. M., Wise, J. R. *et al.* (1978): Chest, **73**, 92.
58. Valdez-Gruz, L. M., Pieroni, D. R. and Roland, J. M. A. (1976): Circulation, **54**, 558.
59. Skub, C., Tajik, A., Seward, J. B. *et al.* (1976): Mayo Clin. Proc., **51**, 81.
60. Feigenbaum, H. (1972): *Echocardiography*, p. 126. Philadelphia: Lea & Febiger.
61. Blades, B. and Beattie, E. (1951): J. Mt Sinai Hosp., **18**, 195.
62. Brøbeck, O. (1948): Acta radiol., **30**, 371.
63. Parker, E. F. and Stallworth, J. M. (1952): Surgery, **32**, 31.
64. Talbot, T. J. and Silverman, J. J. (1953): Arch. intern. Med., **38**, 868.
65. Biancalana, L., Actis-Dato, A. and Ofoegbu, R. (1969): Surgery, **65**, 567.
66. Packard, G. B. and Waring, J. J. (1948): Arch. Surg., **56**, 725.
67. Taylor, B. G., Cockerill, E. M., Manfredi, F. *et al.* (1978): Amer. J. Med., **64**, 360.
68. Gianturco, G. (1975): Amer. J. Roentgenol., **124**, 428.